DOCUMENT RESUME

ED 248 461 CS 007 698

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TITLE Research and Instructional Issues Related to the Enhancement of Children's Decoding Skills through a Microcomputer Program.
PUB DATE Apr 84
NOTE 31p.; Paper presented at the Annual Meeting of the American Educational Research Association (68th, New Orleans, LA, April 23-27, 1984).
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Cognitive Processes; *Computer Assisted Instruction; *Computer Software; *Decoding (Reading); Elementary Education; Microcomputers; Reading Improvement; Reading Instruction; Reading Research; *Reading Skills; Reading Strategies; *Remedial Reading; *Word Recognition
IDENTIFIERS Theory Practice Relationship

ABSTRACT

The efforts to develop and study the effects of a microcomputer program to enhance children's decoding and word recognition skills are described in this paper. The first section of the paper discusses theory and research in the area of cognitive psychology upon which the program, "Construct a Word," is based. The second section describes the instructional goals of the program, and the third provides a description of the components. The fourth section discusses the use of a digitized speech component used in the program for corrective feedback, while the fifth reviews the various materials and activities used to develop decoding and word recognition skills. The remaining sections of the paper discuss a field test of the program, which indicated that it increased the level of decoding efficiency for students whose reading abilities were below grade level. (FL)

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# Research and Instructional Issues Related to the Enhancement of Children's Decoding Skills Through a Microcomputer Program

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CS007698

Paper presented at the annual meeting of the American Educational Research Association, New Orleans, Louisiana, April, 1984.

## Introduction

In this paper, we describe our efforts to develop and study the effects of a microcomputer program to enhance children's reading skill. The program, which is one of several being developed at LRDC, was derived from research of the past ten years on the cognitive processes involved in skilled reading, as well as the processes which are sources of reading problems.

This research has emphasized the need to consider issues relevant to a variety of processes when designing remedial instruction. These include decoding and word recognition, vocabulary knowledge, language comprehension and meta cognitive processes. As a result, we have already begun to design a variety of programs, each emphasizing a different set of issues related to remedial reading instruction. In this paper, however, we will direct our discussion to a computer program called "Construct a Word," (Beck & Roth, 1984) which was designed to enhance decoding and word recognition skills. In addition to describing the program, we'll discuss the theory and research upon which it is based as well as some research which assesses its instructional effectiveness.

## Rationale: Research and Theory in Cognitive Psychology

There are two areas of work which are relevant for understanding the rationale for our instruction. The first area involves advances in the psychology of attention within the human information processing approach. It suggests that performance on tasks like reading can be understood by referring to systems of interacting cognitive processes. This approach emphasizes that the component processes of any complex

skill must occur simultaneously for the task to be completed successfully. What is more important for our purposes is the recognition that component processes must occur in a system which is limited in attentional capacity; people can not devote their attention to too many things at once. Therefore, if a task requires attention to too many subprocesses, some of the processes will not occur effectively and overall performance will be slow or break down altogether.

The reason people are able to perform tasks which require that several subprocesses occur simultaneously is that some of those processes have become automatic -- i.e., they are so well learned that they require little attentional capacity to occur. Schneider & Schiffrin (1977) have used the terms automatic and controlled to refer the amount of attention necessary for a process to occur successfully. Automatic processes occur rapidly, demand very little attention and as a result, can occur simultaneous with other processes. Controlled processes, on the other hand, make greater demands on attention and cannot occur simultaneously with other processes. The distinction is not meant to imply a strict dichotomy between two types of processes. We view the attention required by processes to vary along a continuum of efficiency; the more efficient a process, the more quickly it occurs and less attention it requires.

The main points of this research are (1) performance at complex tasks can be understood be referring to the interaction of their component processes, (2) these processes must occur simultaneously in a limited capacity system, (3) successful performance will occur only if some of the necessary processes have become automatic (Perfetti & Roth, 1981; Perfetti & Lesgold, 1977). and, (4) the skilled individual at

any task has many automatic low-level processes and can devote attention to higher order processes. In contrast, the less skilled individual spends a great deal more attention on lower level processes and performs the overall task more slowly and less completely.

This analysis has been applied to the study of reading. Reading requires many subprocesses to occur at once (identifying words, accessing word meaning, parsing syntax,integrating sentences, relating meaning to prior knowledge, making inferences, solving problems, etc). Numerous studies have demonstrated that skilled readers can do all of this because the basic processes of word recognition have become automatic (Perfetti & Roth, 1981; Perfetti & Lesgold, 1977). Less skilled readers, on the other hand, have weak decoding and word recognition skills, and as a result spend enormous amounts of attention simply identifying words. As a result, they often have little capacity left for the critical high level processes. These are the students who read so slowly that by the time they've gotten to the end of a sentence, they've often forgotten earlier information (Perfetti & Goldman, 1976). To make matters worse for less skilled readers, ineffective word level processes usually drain attention from comprehension processes which are also <u>weak themselves</u> thus causing further breakdown in comprehension (Perfetti & Lesgold, 1977, 1979).

The attention research provided psychologists with an important framework for understanding the relationship between inefficient word level processes and comprehension. It suggested that word recognition must be made more efficient if improvements in comprehension were to occur. The reason why the basic processes of less skilled readers were inefficient emerged from related work on individual differences in

reading.

The second area of research that provided a rationale for the instructional program was research on differences between the way skilled and less skilled readers identify words. Several insights have emerged from this work. First, skilled comprehenders are able to read individual words more quickly and accurately than less successful comprehenders. Second, the reason they identify words more efficiently is that they have rich, tacit knowledge of the orthographic regularities of English words. They are be able to decode words automatically by referring to multi-letter subword units in addition to sight word knowledge. Many less skilled readers, on the other hand, lack the ability to use these units and often rely on other information to identify the word. This might include checking the first and last letter and generating a possible response or using memory for the specific letter pattern or shape of the word (Frederikesen, 1982; Biemiller, 1970; Weber, 1970).

The evidence for these conclusions comes from studies using a variety of tasks. In particular, the strongest measure of decoding and the measure which we have adopted to assess the effectiveness of our programs is pseudoword vocalization latency. A pseudoword is a pronounceable letter string which is not an actual word in English (e.g., glip, stam, fent). Pseudowords always contain letter patterns which occur in real words, so they are consistent with English orthography. They can not be pronounced except by using decoding processes which attend to all parts of the letter string.

In a typical vocalization task, a word or pseudoword is presented on a screen and the time for a child to begin to vocalize the word is recorded. The important finding using this task is that the time it takes children to vocalize words and pseudowords is the strongest predictor of reading ability in the elementary school grades, even stronger in some cases than listening comprehension (Curtis, 1980; Lesgold & Curtis, 1981).

Together with the work on attention, we take these findings as evidence that readers differ widely in the efficiency of their decoding processes, that efficiency is a function of the ability to use subword units to identify words and finally, differences in decoding processes are at least partially responsible for problems in reading comprehension. Our instructional goals and the means by which we achieved them followed directly from this interpretation.

## Instructional Goals of Construct A Word

The goal of our instruction was to enhance the decoding and word recognition processes of less skilled readers. We were interested in working with students whose reading levels were one or more years behind the average in the latter part of elementary school instruction. These are the students who, after 3 to 5 years of reading instruction, still are not reading successfully and still lack efficient decoding skills. The reason why these students do not acquire decoding skills when most of their classmates do so without explicit instruction is unclear. One possibility is that they receive fewer reading experiences prior to starting formal instruction. Alternately, they start with similar prerequisites, but require more experience or practice opportunities or

more explicit instruction to achieve the same level of decoding expertise as their peers. In either case, we were interested in designing instruction which would provide opportunities for practice much more extensively than that which usually occurs in the classroom.

In addition, our goal was to design practice activities which promote the use of more efficient processes for decoding words. This involved designing an activity which required students to attend to the subword units that make up words. We wanted to avoid repetitious drill and practice which reinforced existing inefficient strategies for identifying words. Our goal was to provide practice which was instructive. Before discussing some of the additional design considerations, it might be helpful to describe the essential activities in which a child engages while using the program.

## Program Description

The principal activity of Construct A Word is composing words from sets of subword letter strings. Children select consonants, consonant clusters and phonograms that go together to form real words. This activity is incorporated in a game format, which motivates an enormous amount of efficient practice in a short period. We use properties of successful computer games to maintain interest and a high rate of responding and do so in a way to focus attention on the instructional activity. The play of the game is best understood from an example.

Figure 1 contains an example of a computer screen from the program. The left column contains 3 word beginnings (l, p, t) and the other 9 strings are word endings (ife, and, ot, og, em, one, ime, in, ake). Children use either joystick or keyboard to select a beginning and an ending that form an English word. When a beginning and ending are selected that make a real word, the word appears in the word box on the right. The goal is to make enough different words to fill the stack (in this case, 5). While the words are being made, a clock keeps track of the elapsed time at the top of the screen. When the word stack is full, the screen clears and feedback is given about the time and number of words made.

As you can see, the principal activity of the game is identifying multiletter, subword strings and finding combinations of these strings which form real words. The assumption is that with extensive practice, these units will be used automatically to enable more efficient identification of the words in which they are contained. Students do receive practice on the specific words they form with these beginnings and endings, but our goal was to develop facility with letter patterns which will generalize to words not specifically taught. We'll discuss this distinction and the materials we developed later.

Figure 2 describes the point in the game when the word box has been filled for the first time. In this case, the student took 35 seconds to make 5 words. This time is important because it is used as a baseline for the next round of play. Each time the game is replayed, students must make one additional word and do so in just 10 seconds more than the previous time. For example, if a child took 35 seconds to make 5 words, then 45 seconds would be provided to make 6 words. Each time the word

stack is filled before time runs out, the new time is adjusted to 10 seconds more than the actual time that elapsed in the previous board. The significance of this feature is that the program attempts to maintain a challenging level of play which is determined strictly by each students performance.

Each time a new board is played, the same set of word parts are used, with the positions randomized. If at some point, time runs out before the required number of words is made, students drop back to attempt the previous stack size again in the same time. As a result, more and more words are added to the stack up to a maximum of 13 words. Figure 3 illustrates the maximum stack size.

The Use of Speech

A very important instructional feature of the program is the use of speech for corrective feedback and help. We use digitized human speech stored on diskette. The speech is reproduced by a device called Supertalker designed by Mountain Computer Co., which plugs into an expansion slot in an Apple or IBM PC. The quality is much greater than synthesized speech and is comparable to that of a cassette tape recorder.

Speech is crucial for communicating symbol-sound correspondence and is used in two ways. First, when a student makes a selection which does not form a real word, the computer pronounces the non-word that was actually made and indicates that it does not spell a real word (see figure 4). This type of feedback is unique among computer programs in that it explains the error that the child committed. Occasionally, children will construct nonwords because they've misread an ending or

beginning or mispronounced the string that is produced when they are combined. Without speech, there would be no way to seize this opportunity to correct an error so informatively.

In addition to providing feedback, hearing and seeing a nonword that a child constructed is instructive itself, since all of the non-words that can be produced are regular patterns and could appear as parts of real English words (e.g., "lem" in lemon, "pand" in expand, "lin" in lint). As a result of the use of speech in this manner, children receive effective feedback without punishment. The main incentive for avoiding errors is the fact that the screen freezes while the clock keeps ticking for four seconds during the correction period Thus, errors hinder one's attempts to "beat the clock", but leave no obvious, punishing record.

A second use of speech in the program is in the student-requested HELP sequence. Whenever a student would like help finding a word, the computer pronounces one which has not been used yet. Simply pronouncing a word is usually enough help for children to make the word, but if it isn't, the component letters flicker on the screen. The auditory HELP feature introduces new words that would not have been made otherwise and helps children when they work on large word stacks and have lost track of which words have not been made.

Materials

Students play with the same set of 12 word parts until they've completed a stack size of between 10 and 13. Most children like to play until 13, although we prefer to allow them the option to move to new materials when they've reached some level of mastery at the smaller sizes. In addition, they can play a second game, called TIME, with the same materials which involves the same word-making activity. The games differ in that one game varies the number of words to be made while the other keeps it constant and places more emphasis on time per se. The function of the different formats is to promote extended motivated practice.

There are 20 sets of word parts, that are roughly sequenced according to the length and complexity of the words that they form. The same game is played with all the sets; changing levels involves changing diskettes. The sequencing of materials reflects typical orderings of letter patterns that one sees in reading curricula. The sets of materials progress through (1) common CVC's, (2) endings using a long vowel-silent e combination, and (3) beginning and ending consonant clusters and vowel digraphs in increasingly longer words. The goal was to create a pool of some 250 word parts, which when combined across all 20 sets would produce several thousand words either directly, or by replacing just a single letter. We reemphasize that the goal is not to achieve efficient processing for a small set of words that are used in the program, but rather a large set of multiletter subword units which will be present in thousands of other words. In this sense, the program is designed to develop decoding skill which is generalizable.

Assessment of instructional effectiveness

During the course of development, the program was field tested several times in different forms to study issues related to class management, motivation and instructional validity. Currently, we are engaged in a long term experiment on Construct a Word and a related program in an inner city school. We have completed the first phase, in which 70 fourth graders used Construct A Word over three months. The results of this phase of the study will be the focus of the remainder of the paper.

School Setting

With the assistance of the school board we selected two schools whose reading achievement was among the lowest in the city. The programs were used by 70 students in three fourth grade classes in one of the schools. The other school served as a control. The mean California Achievement Test reading comprehension scores were approximately 3.9. There were many children reading 1 and 2 years below national norms on achievement which measure decoding and overall reading comprehension. Thus, we were studying the effects of the program for students who had received 4 years of reading instruction and still did not have adequate word level skills.

Three computers were placed in the back of each of the three classrooms. Students were trained to use the computers and programs and the scheduling scheme that we created. Each student was assigned to 3 or 4 twenty-minute sessions each week and was individually responsible for following the schedule. Over 12 weeks, students spent an average of approximately 14 hours working with the program. In order to keep track

of student progress and to provide information about their use of features in the program, data collection routines were included as part of the program. As a result, we were able to collect virtually every response and related time information, while the program was in use. Although these data are extremely interesting, we will not discuss them here, but focus on the data from the assessment tasks.

Our goals in assessing the effects of the program were threefold. We wanted to determine (1) the extent to which the program increased decoding efficiency, (2) whether changes in efficiency were general and not limited to words which were specifically part of the instruction, and, (3) whether improvements in decoding would be general enough to persist when students read words for meaning.

In order to answer these questions, we designed and administered several tests before and after the instruction. For present purposes, two tasks are most relevant.

The first is the pseudoword vocalization task mentioned earlier. Each student was presented with 20 pseudowords, individually, and the time required for the student to begin to vocalize each one was measured. Improvements in pseudoword vocalization latency could be interpreted as increases in decoding efficiency. The generality of the improvements were assessed by creating pseudowords which could not have been specifically practiced or heard in the program. These contained beginnings and endings which occurred in the program but never in the same game. For example, the ending "ime" appeared in one set in the program and could have been paired with "p" or "st" to make pseudowords in the program. Therefore, on the vocalization test "ime" was used with "tr", which appeared in another set, elsewhere in the program. Using

materials like these enabled us to assess whether improvements in students' decoding efficiency transferred beyond specific items that may have appeared in the program.

The third goal, assessment of transfer of improvements in decoding efficiency to tasks requiring access to word meaning, was addressed by timed semantic decision task. A typical item in the task involved deciding whether "a person could do" the following: "build a house," "grip a tool," "drive a glass," "drink a tire." Thirty phrases were constructed for this question from word parts that appeared in the program. Phrases were presented individually and children responded "yes" or "no" by pressing one of two buttons. Response times for correct responses were recorded as in the pseudoword vocalization task.

## Results

In order to assess the effects of the instruction for readers at different levels of ability, students were assigned to one of three groups based on a combination of their achievement scores and performance on the pretest of the two tasks. The three lowest groups had mean Woodcock decoding subtest scores which correspond to the following grade equivalents (low groups = 1.9, medium = 3.5, high group = 5.1); the tests were administered at the beginning of the fourth grade (4.2).

In both tasks, the analysis consisted of a comparison of times for correct responses on the pre and post tests as a function of reading ability (high, medium and low) and treatment condition (experimental vs control).

The results for the pseudoword vocalization task are presented in figure 5. The only significant differences between pre and post tests were for the subjects of low and medium ability in the experimental group (P's < .05). There were no significant changes in performance for the control Ss or for the highest ability group receiving the instruction. The latter group's responses were extremely fast on both pre and post tests. The differences between this group and the others, which existed prior to instruction, was reduced substantially but still remained after instruction.

The data for the semantic task were analyzed in a similar way and are presented in Figure 6. The pattern of results was virtually identical to that from the pseudoword vocalization task. Again, the only significant pre-post changes were for the subjects of medium and low ability who participated in the instruction. The differences among the three ability groups were reduced following instruction, but the readers of highest ability were still faster than their less skilled classmates.

## Discussion

The results can be evaluated in terms of the assessment goals and rationale of the instruction. First, the instruction increased the level of decoding efficiency for those students whose reading ability was below grade level. This was particularly true for students whose standardized achievement tests indicated they were reading below level that would be expected of 2nd graders (2 years behind grade level).

Second, the improvements were not specific to words that could have been heard or read in the program. The items on the tests never appeared in the program, although they could be constructed from beginnings and endings which were practiced in the program.

Finally, the instruction resulted in improvements in decoding ability which facilitated the rate at which students read words in a task which required accessing and making decisions about meaning. This finding is important because the instruction focused on subword units and isolated words and provided no instruction on word meaning per se. Thus, although the program instructed one component of reading in isolation of all others, it did improve performance on that component when it was necessary in a task which required attention to semantic processes as well.

An alternative explanation of the response time improvements is that students who used the program may have become more concerned with responding fast because of the emphasis on time in the program. In other words, perhaps students became more impulsive and responded more quickly at the expense of accuracy. This explanation can be ruled out by noting that the experimental subjects did not become less accurate on either task. In fact, they became more accurate on both tasks. In addition, there have been numerous studies of tasks like these which rule out any relation between reading ability and reaction time or ability to vocalize a word per se (when decoding is eliminated, as in picture naming or when the word is known in advance (Curtis, 1980; Lesgold & Curtis, 1981; Perfetti & Lesgold, 1977).

The instruction resulted in significant improvements in decoding speed for the less skilled readers. The performance of the lowest group on the post test approached that of the medium group on the pretest. Thus, a difference between two groups whose achievement scores were one and a half years apart was almost eliminated after 14 hours of instruction. We intend to confirm this assessment with standardized achievement tests over the next few months.

It is important to note that, although the improvements were substantial, the instruction did not raise performance of the least skilled readers to the level of the most skilled readers. In fact, the least skilled readers still spent over a second more to identify a pseudoword. There are several possible explanations of this. First, it is possible that these readers require much more practice to reach this level of performance (which may have been as much as 3-4 years more advanced). Deficits which emerge over four years may take more time to be eliminated. In addition, it is likely that the deficit remained because the program did not address all aspects of decoding problems. Although the program contained word endings which included vowels and vowel digraphs, it did not instruct or practice these typically difficult word parts directly.

The effect of more practice and instruction on other aspects of decoding will be assessed in a continuation of this study over the next few months. The same students are using a second program, Hint and Hunt, which provides instruction and practice on difficult vowel combinations.

Finally, it is important to consider the extent to which the effects of the program continue to enhance decoding skill as children engage in classroom reading activities. Students may have acquired a word recognition strategy that enables them to analyze and learn more about the orthographic structure of words while they read. We have discussed the goals of the instruction in terms of learning subword units. It is also possible that the outcome was a greater tendency to attend to interior parts of words and to attempt to decode unfamiliar words by extending their knowledge of words with similar letter patterns or structure. We expect to be able to assess long term effects of the instruction of this nature in post tests administered in the future.

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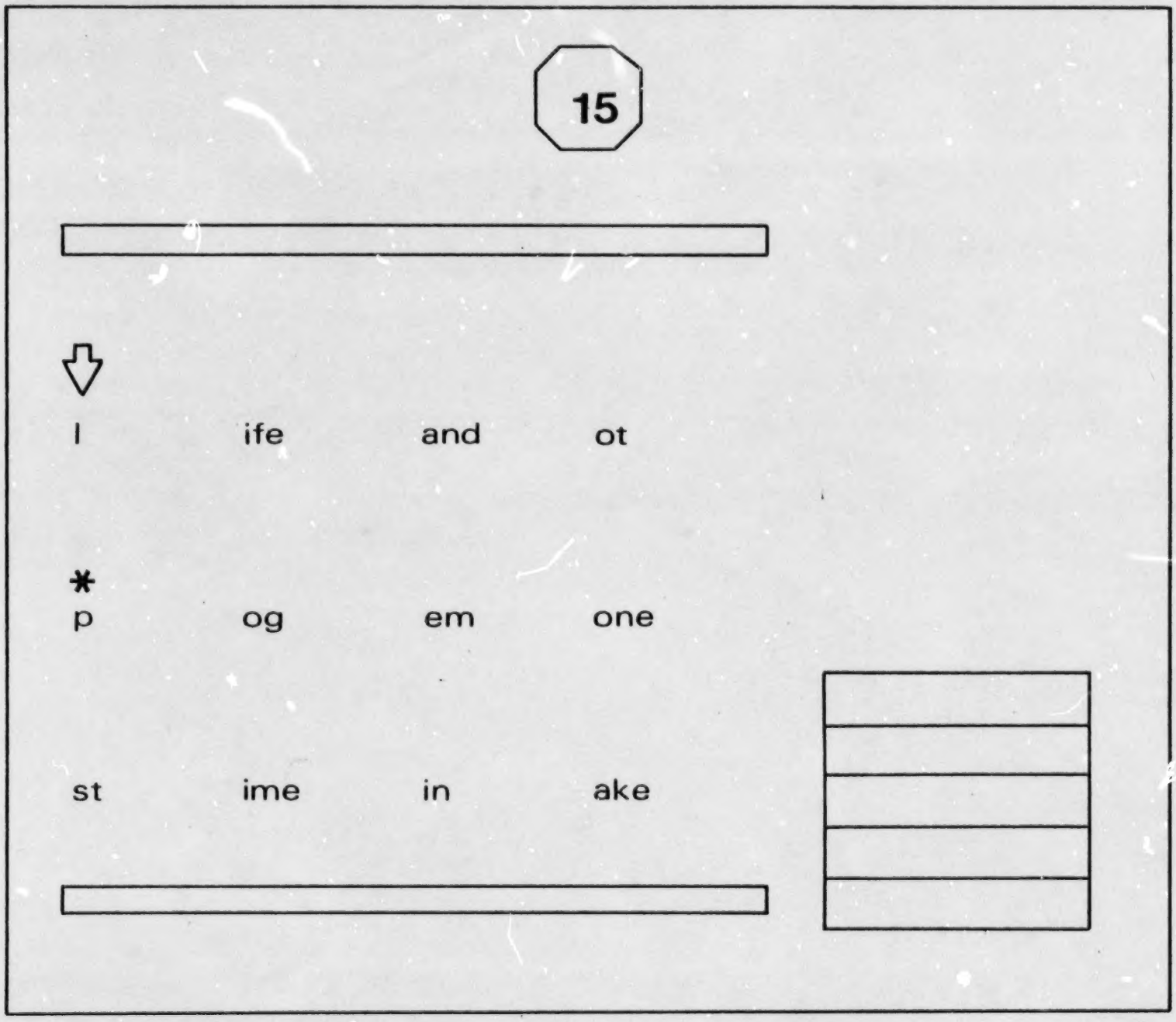



Figure 1

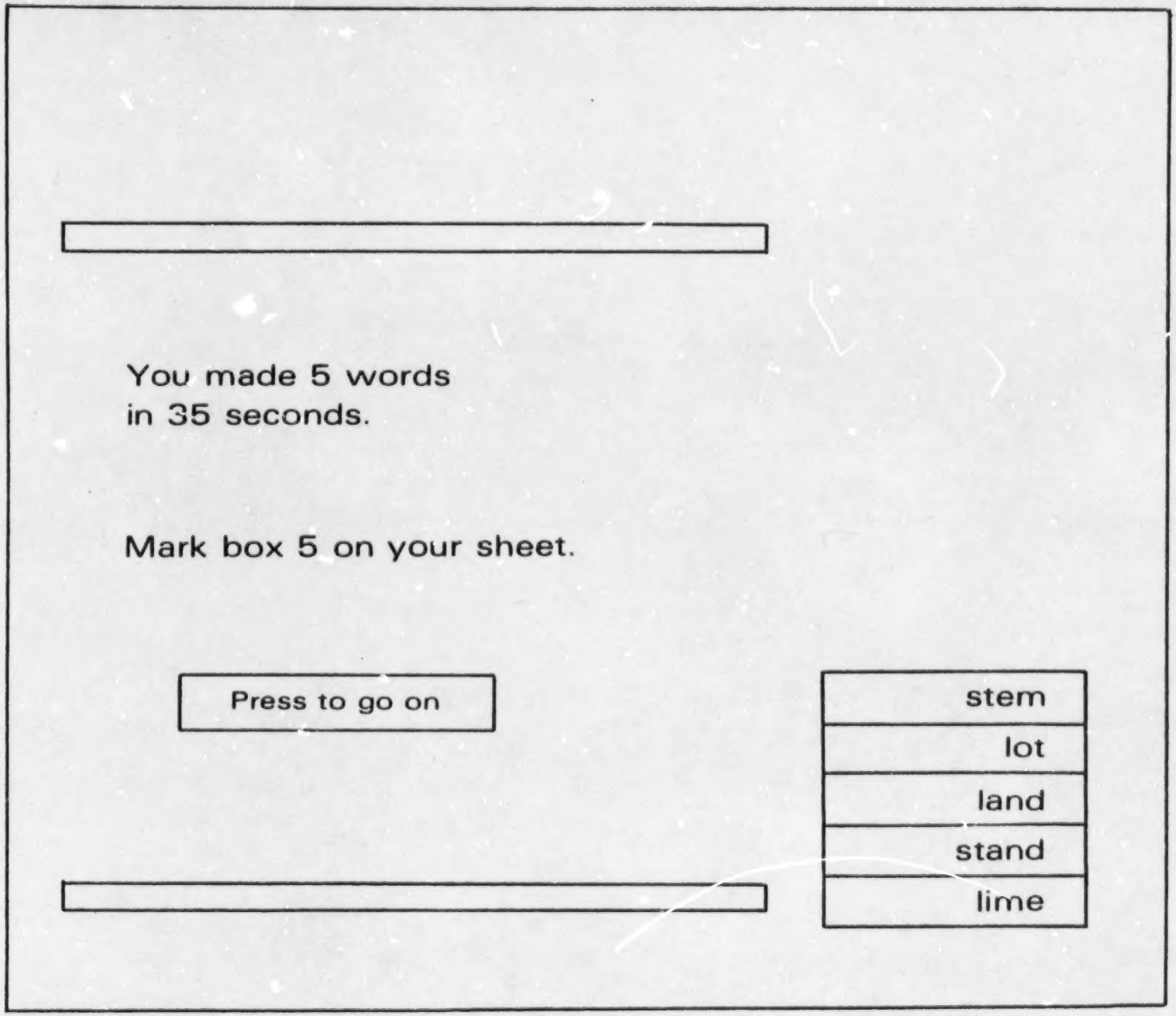

You made 5 words
in 35 seconds.
Mark box 5 on your sheet.
Press to go on
stem
lot
land
stand
lime

Figure 2

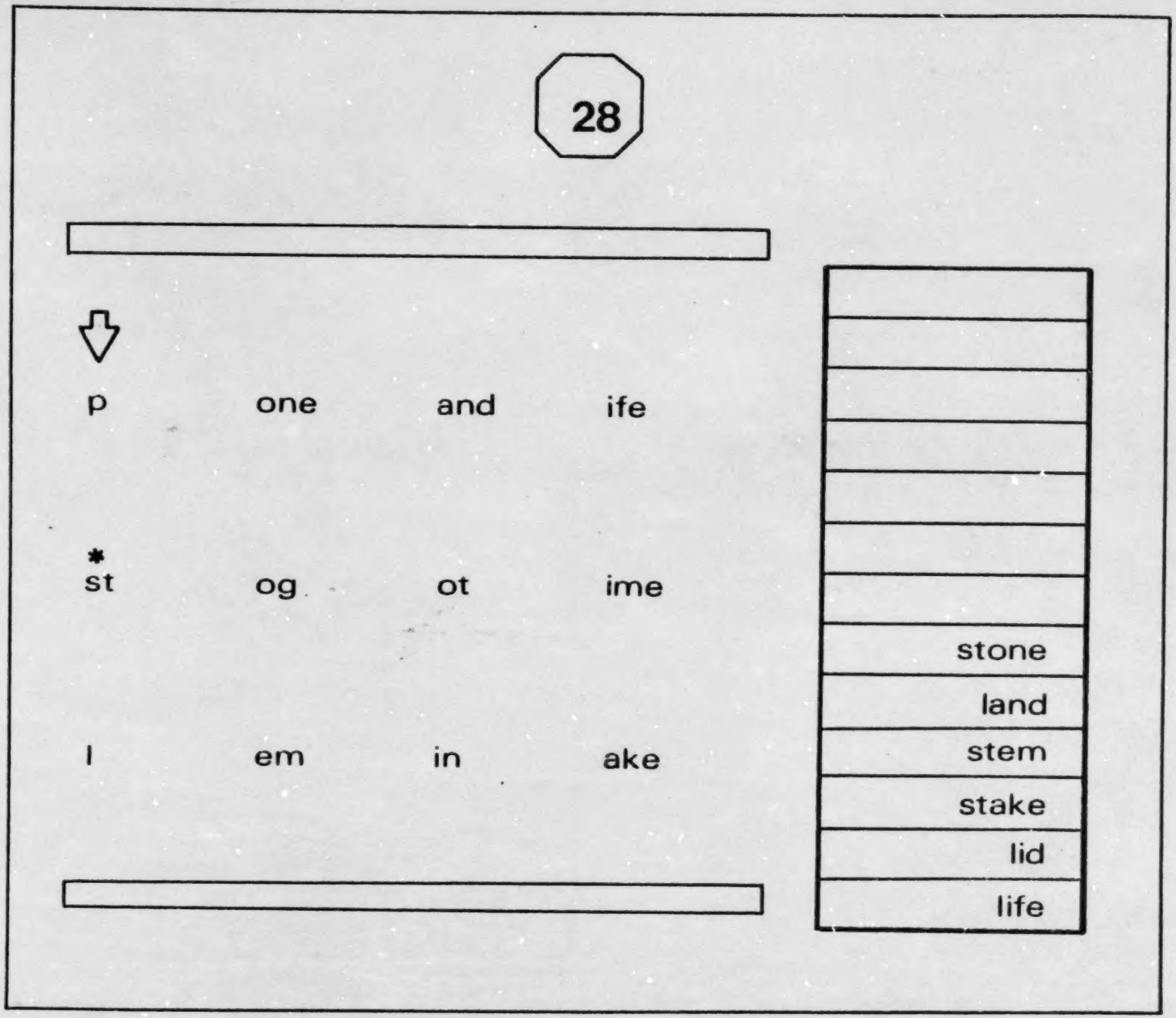
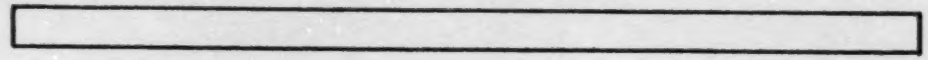

28
p one and ife
*
st og ot ime
l em in ake
stone
land
stem
stake
lid
life

Figure 3

Stime does not spell a real word.



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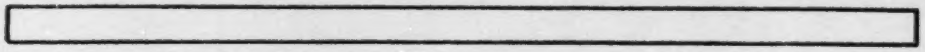

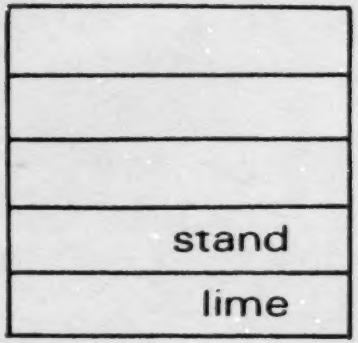


Figure 4

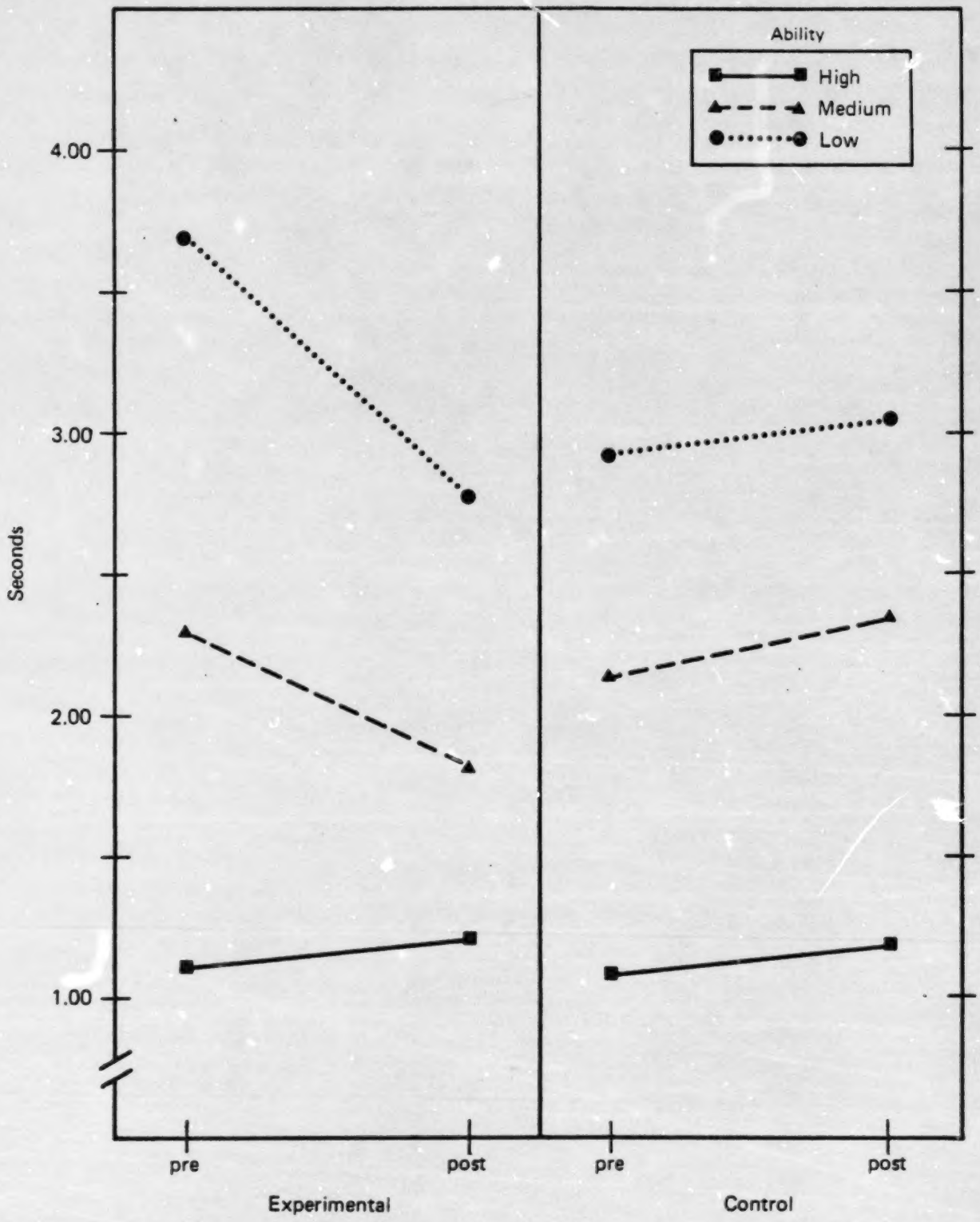


Figure 5. Mean vocalization latency for nonwords as a function of reader ability, treatment condition and time of testing.

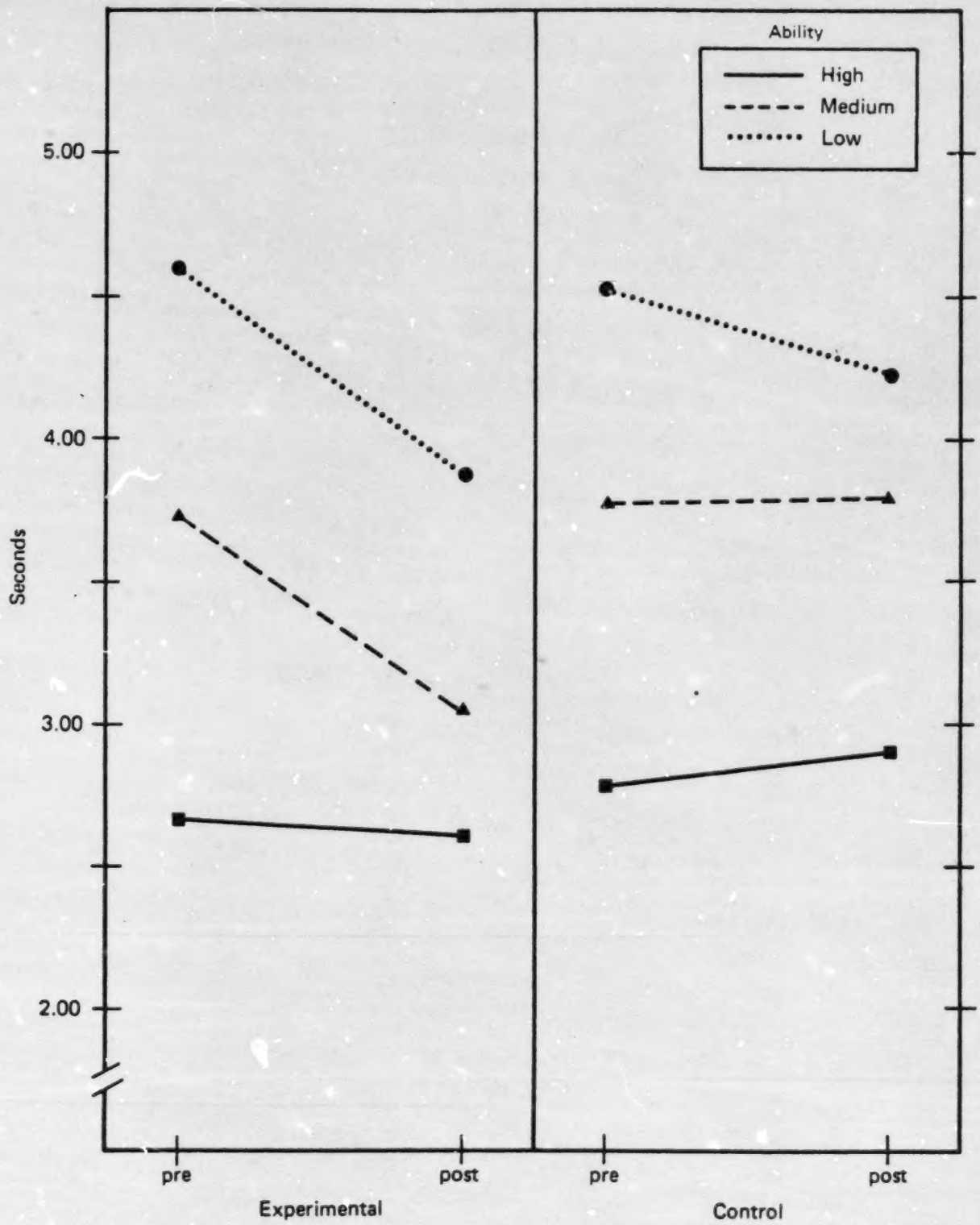


Figure 6. Mean response latency for semantic decisions as a function of reader ability, treatment condition and time of testing.